(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 120 856 A1

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 158(3) EPC

(43) Date of publication:
01.08.2001 Bulletin 2001/31

(21) Application number: **00935227.9**

(22) Date of filing: **07.06.2000**

(51) Int Cl.[7]: **H01Q 3/46**, H01Q 21/00

(86) International application number:
PCT/ES00/00203

(87) International publication number:
WO 00/76026 (14.12.2000 Gazette 2000/50)

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **07.06.1999 ES 9901248**

(71) Applicant: **UNIVERSIDAD POLITECNICA DE MADRID**
28040 Madrid (ES)

(72) Inventor: **ENCINAR GARCINUNO, José Antonio**
Ciudad Universitaria, 28040 Madrid (ES)

(54) **PRINTED CIRCUIT TECHNOLOGY MULTILAYER PLANAR REFLECTOR AND METHOD FOR THE DESIGN THEREOF**

(57) The invention relates to a printed circuit technology multilayer planar reflector reflecting the electromagnetic field from a feed (110) forming a collimated or conformal beam by performing adjustments in the reflection coefficient phases. The phase control is effected by adjusting the dimensions in each element (300) that is formed by several layers of conductive patches (400), (410), spacers (420), (430) and conductor plane (440). The inclusion of two or more layers reduces sensitivity to manufacturing tolerances and improves the bandwidth of the reflector. The invention also relates to a design method for obtaining photomasks involving the following steps: 1) Defining the phase shift in each element; 2) adjusting the dimensions of each element at the central frequency; c) performing fine adjustments to meet specifications. The reflector according to the invention can be used as antenna of terrestrial and satellite communications, collapsible antenna and conformal beam reflector.

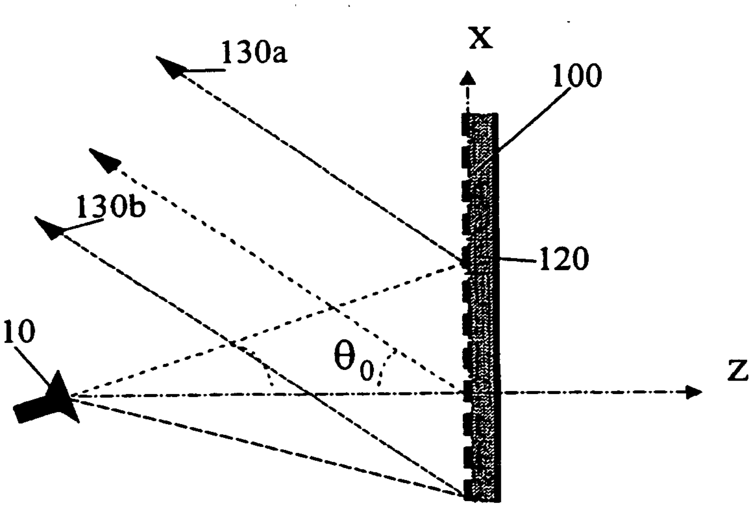

Fig. 1

BEST AVAILABLE COPY

EP 1 120 856 A1

Description

Subject:

[0001] This invention is framed in the telecommunication, radar and space technology sectors.

Prior state of art:

[0002] This invention is related to planar reflector antennas, as an alternative to parabolic or shaped reflectors that are used in radar systems, in terrestrial and satellite communications, in both earth and flight segments.

[0003] Planar reflectors have been used previously and are known as "reflectarrays." A reflectarray consists of an array of radiating elements (120) on a plane with a certain adjustment that allows a collimated reflected electromagnetic field to be obtained when it is illuminated by a feed (110) (figure 1) in a similar way to that of a parabolic antenna. This is equivalent to obtaining a reflected field with a planar wave front, i.e. with a progressive phase distribution on the planar surface. The reflectarray concept is old, as it can be seen in a number of references, [D. G. Berry, R. G. Malech W. A. Kennedy, 'The Reflectarray Antenna ', IEEE Trans. on Antennas and Propagat., Vol. AP-11, 1963, pp.646-651] and [M. I. Skolnik, 'Radar Handbook', McGraw Hill, 1970, pp. 11.54-11.60]. The reflectarrays described in these references are built using waveguides as radiating elements, resulting in heavy and bulky reflectors. More recently, printed reflectarrays have been used [R. E. Munson, H. A. Haddad, J. W. Hanlen, 'Microstrip Reflectarray for Satellite Communications and RCS Enhancement or Reduction ', patent US4684952, August 1987], [R. D. Javor, X.. D. Wu, K. Chang, 'Design and Performance of to Microstrip Reflectarray Antenna ', IEEE Trans. on Antennas and Propagat., Vol. 43, No. 9 Sept 1995, pp.932-938] and [D. M. Pozar, S. D. Targonski, 'A Microstrip Reflectarray Using Crossed Dipoles ', 1998 IEEE Intl. Symposium on Antennas and Propagat., pp. 1008-1011] that use rectangular or cross-shaped metallic patches on a grounded dielectric, called microstrip antennas, as radiating elements. An array of 3x3 square patches is shown in figure 2.

[0004] Microstrip antenna arrays are well-known [R. J. Mailloux, J. F. McIlvenna, N. P. Kernweis, 'Microstrip Array Technology ', IEEE Trans. on Antennas and Propagat., Vol. 29, No. 1 Jan. 1981, pp. 25-37], and they are used as high-gain antennas as an alternative to reflectors. Microstrip arrays consist of a group of printed metallic patches that are fed individually by means of a complicated feeding network to get the progressive phase distribution on the array surface. These arrays have advantages over reflectors as their low profile, low volume and weight, low cross polarisation and ease of manufacture by conventional photo-etching techniques. However, the frequency band is narrow and the antenna efficiency is reduced at microwave frequencies, due to the losses in the complex feeding network.

[0005] In the reflectarray, since the feeding is the same as that of reflectors, the inconveniences of microstrip arrays as a result of the feeding network are eliminated, i.e. the design and manufacture processes are simplified, losses are reduced and the antenna efficiency is improved. Compared to reflectors, the reflectarrays have the advantage of their low profile, smaller distortion and lower levels of cross polarisation, at the cost of a very narrow band, as described in [J. Huang, 'Bandwidth study of Microstrip Reflectarray and a Novel Phased Reflectarray Concept', 1995 IEEE Intl. Symposium on Antennas and Propagat., pp. 582-585].

[0006] The classic implementation of the adjustment in rectangular microstrip patches to get a progressive phase distribution consists of connecting transmission line segments of different lengths to the printed elements, as shown in patent [US4684952, 'Microstrip Reflectarray for...']. In this configuration, each patch receives the signal from the feed, which is propagated along the transmission line until the end, which can be either a short or open circuit, where it is reflected, propagated back and radiated by the microstrip patch with a phase shift proportional to twice the line length. The printed line segments generate dissipative losses and spurious radiation that cause a reduction in the antenna efficiency and an increase in the cross polarisation levels.

[0007] Other techniques have also been used to get the phase adjustment in each element of the reflectarray, such as the size variation of the resonant patches [D. M. Pozar, T. Metzler, 'Analysis of to Reflectarray Antenna Using Microstrip Patches Variable of Size ', Electronic Letters, 15th April 1993 Vol. 29 No. 8, pp. 657-658], the use of phase shifters [J. R. Profera, E. Charles, 'Active Reflectarray Antenna for Communication Satellite Frequency Re-use', patent US5280297, January 1994], or by the voltage control in diodes connected to the radiating elements [F. Gautier, et al., 'Phased Reflector Array and an Antenna Including such an Array ', patent US5148182, September 1992]. In the patent [US5280297, 'Active Reflectarray Antenna.... '] an active reflectarray is described, where signal processing is carried out in each element by using devices such as, circulators, amplifiers and phase shifters. The inclusion of active devices allows the reflected signal to be amplified, but the reflector manufacturing process is significantly more complex. In patent [US5148182, 'Phased Reflector Array....'] a reflectarray is described in monolithic integrated circuit technology for applications in millimetre wave bands, where varactor diodes are integrated together with the radiating elements. The diode capacity is varied to get the adjustment in the phase of the reflected field. This technology requires very sophisticated production processes and it is reduced to applications at very high frequencies, and for small-sized

reflectors.

[0008] The phase adjustment by means of the variation of the resonant patch length, as shown in figure 3, is very easy to carry out by using dielectric sheets with printed metallic patches. Also the inconveniences due to the printed lines, that appear in reflectarrays with line segments, are eliminated in this implementation.

[0009] The operating principle of the reflectarrays of variable-sized printed elements is based on the fact that the phase of the reflected wave varies with the resonant length of the elements. A microstrip patch is a resonant antenna, so that its length should be approximately half a wavelength in the dielectric. If the patch length is modified in an array of identical rectangular patches on a ground plane, as shown in figure 2, the module of the reflection coefficient remains equal to one, owing to the ground plane, but the phase of the reflected wave changes. The total range of phase variation that can be achieved by varying the length of the patches depends on the separation between patches and ground plane, i.e. the thickness of the substrate (210). For thicknesses smaller than a tenth of wavelength, a 330° range can be achieved, which is enough for carrying out practical designs, but this range diminishes for thicker substrates. Because of this, the reflectarrays based on this adjustment technique use thin dielectric substrates. However, the phase variation versus the length is strongly non-linear, exhibiting very rapid variations near the resonance, and very slow in the extreme values, as can be seen in figure 6. The rapid phase variation makes the phase distribution very sensitive to manufacturing tolerance errors. Because of the non-linear behaviour, the phase is very sensitive to variations in frequency, significantly reducing the working band of the reflectarray.

[0010] An important application of reflectarrays is their use as dual polarisation reflectors for frequency reuse. In a communications satellite with frequency reuse, independent signals are transmitted and received through the different channels, with an overlap in their frequency bands. The adjacent channels are transmitted or received in orthogonal polarisations, to allow frequency reuse. Although the two orthogonal polarisations can be circular, clockwise and anti clockwise, the most common case is to use two linear polarisations, designated as vertical and horizontal. The frequency reuse requires a very high isolation between polarisations, which cannot be achieved with parabolic or shaped reflectors. To obtain this isolation between polarisations, two superposed grid reflectors with a separate feed for each polarisation can be used. Each grid reflector is made up of parallel metallic strips on a parabolic or conformal surface, so that it is transparent to one of the polarisations and acts as a reflector for the orthogonal one.

[0011] A reflectarray acting as a dual polarisation reflector for frequency reuse has been patented [J. R. Profera, E. Charles, 'Reflectarray Antenna for Communication Satellite Frequency Re-use Applications ', patent US5543809, August 1996], which is made up of two arrays of orthogonal dipoles of variable lengths. The array of vertical dipoles acts as a reflector for the vertical polarisation and that of horizontal dipoles for the other polarisation. The invention includes reflectarrays in both, printed and non-printed technology, and also the possibility of including segments of transmission lines to obtain phase adjustment in the 360° range. But, like all reflectarrays based on radiating elements of variable sizes, this reflectarray has the inconvenience of a very small bandwidth, and is not suitable for most commercial applications.

[0012] Keeping in mind that the more restrictive limitation for both microstrip arrays and reflectarrays is their narrow band operation, multilayer arrays have been used to increase the working frequency band, as shown in [J. T. Aberle, D. M. Pozar, J. Manges, 'Phased Arrays of Probe-Fed Stacked Microstrip Patches ', IEEE Trans. on Antennas and Propagat., Vol. 42, No. 7 July. 1994, pp. 920-927]. These arrays are made up of two or more stacked layers of patch arrays. An application of stacked reflectarrays was also proposed, in which the phase adjustment is carried out in a single dimension for two separate frequencies [J. A. Encinar, "Design of a dual frequency reflectarray using microstrip stacked patches of variable size", Electronics Letters, 6th June 1996 Vol. 32 No. 12 pp. 1049-1050]. In this reference, two stacked arrays are used, with patches of very different sizes, which are designed independently for each frequency, so that, the bandwidth limitations are kept the same as that of single layer reflectarrays. Previous to this invention, and to the author's knowledge, multilayer reflectarrays have not been proposed for improving the electrical characteristics with respect to single layer reflectarrays.

[0013] For the analysis of multilayer structures with periodic metalizaciones, different techniques based on numerical methods in electromagnetism have been proposed. From all of them, the reference [Ch. Wan and J. A. Encinar, 'Efficient Computation of Generalized Scattering Matrix for Analyzing Multilayered Periodic Structures', IEEE Trans. Antennas and Propagat., Vol. 43 No. 11, Nov. 1995, pp.1233-1242] must be mentioned, which uses the Moments Method, and it is very efficient and flexible for the analysis of multilayer configurations, because the analysis of each layer is carried out separately. These techniques have been used in the analysis and design of Frequency Selective Surfaces, and multilayer microstrip arrays, but not in the design of multilayer planar reflectors with similar characteristics to parabolic or shaped reflectors.

Description of the Invention

[0014] As mentioned in the previous section, the planar reflectors based on printed circuit technology that exist until now have several disadvantages. On the one hand, the reflectarrays that use segments of microstrip line for phase

adjustment have a lower efficiency and a higher level of cross polarisation owing to the losses and the spurious radiation of the lines respectively. The reflectarrays with variable sized radiating elements do not present these problems, but on the other hand they are very sensitive to errors in manufacturing tolerance, and their operation is limited to a very narrow band, because of the rapid variation of the phase with the length.

[0015] A way to achieve a smoother behaviour of the phase as a function of the length consists of increasing the thickness of the substrate (210), but this significantly reduces the total phase range. It must be kept in mind, that for the design of a reflectarray, phases of the reflection coefficient are required in the range from 0 to 360°, and they cannot be achieved for a thicker substrate.

[0016] In this invention, a reflectarray configuration that consists of two or more array layers with patches of variable sizes (Figs. 4, 5 and 8) is proposed. This configuration produces a more linear behaviour of the phase versus size, and permits realisations less sensitive to manufacturing tolerances and with a larger bandwidth.

[0017] The innovation of stacking two or more array layers allows the phase shift in the reflected field to be increased to values greater than the 360° required for the reflectarray design. An array of rectangular metallic patches behaves as a resonant circuit, in which the phase of the reflected field varies with the size of the patches in a range of up to 180°. When the array is placed on a metallic plane, as in figure 2, the maximum range of phase shift approaches 360°, if the separation between the patches and the plane is very small (much smaller than λ, λ being the wavelength). Figure 6 shows the phase as a function of the side for an array of square patches at frequencies 11.5, 12 and 12.5 GHz. In this case, the phase range is 305°, for a separator substrate (210) with dielectric constant 1.05 and 1 mm. thick (0,04λ). The phase shift range decreases as the separation increases between patches and metallic plane, i.e. the thickness of the substrate (210). When two or more array layers are used, each of them behaves like a resonant circuit, and the phase of the reflected field varies with the patch size in a similar way to that of one layer, but the phase shift can reach values of several times 360°. Therefore, with several array layers, the separation between them, and the separation between the first array and the metallic plane, can be increased to achieve a smoother and more linear behaviour of the phase as a function of the patch size, maintaining a range for phase shift greater than 360°. Figure 7 shows the phase curves as a function of the square patch size, at the same frequencies, for two stacked arrays on a ground plane with 3-mm. thick separators, (420) and (430).

[0018] An object of this invention is a planar reflector, or reflectarray, in multilayer printed circuit technology. Figure 4 shows a simplified lateral view of the multilayer reflectarray. This configuration allows the feed to be located at any angle and to redirect the reflected beam in any direction of the space (θ_0, φ_0), being θ_0 and φ_0 the usual angles in spherical co-ordinates, by means of an appropriate design of the reflection coefficient phase in each element of the reflectarray. This planar reflector reflects the electromagnetic field coming from a feed (110) located at a focal point, forming a collimated beam in a given direction at a given frequency. In a reciprocal way, the reflector receives a collimated beam from a direction at a given frequency and reflects it, concentrating it at the focal point where the feed (110) is located. As a particular case, the phase in each element can be adjusted so that the planar reflector exhibits the same radiation characteristics as a parabolic reflector. The phase control is carried out by adjusting the dimensions in each radiating element. Each element of the reflectarray consists of several stacked layers of conductive patches separated by dielectric sheets, all of them above a conductor plane, as shown in figure 5 for the case of 2 layers. This description is based on rectangular shaped patches, but the same effect is obtained using conductive patches with other geometric shapes, in which at least two dimensions can be independently adjusted to control the phase of the reflection coefficient for the two orthogonal polarisations of the incident field on the reflector. For example, cross-shaped metalisations can be used, controlling the phase for each polarisation with the length of each arm of the cross.

[0019] For the analysis of the structure, a local periodicity approach is considered, which assumes each element with its dimensions, but in a periodic environment, and the phase of the reflection coefficient is calculated as a function of the patch side. The periodic structure is analysed by a previously developed full wave method, which is based on the Moments Method in the spectral domain.

[0020] This invention allows the realisation of planar reflectors so that their characteristics are not sensitive to manufacturing tolerance errors. In the proposed reflectarray, the required precision is not greater than 0.1mm, making the manufacturing processes both simpler and cheaper. An object of this invention consists of manufacturing each layer of the planar reflector, made up of printed rectangular metallisations on sheets of dielectric material, by means of conventional photo-etching procedures, such as those used in the production of printed-circuit boards. These processes consist of the selective elimination of conductive material starting from a dielectric sheet covered with a conductive film, by photo-etching and chemical etching techniques. The selective elimination of the conductive material can also be carried out by laser, or by cutting the conductive patches with a cutting plotter, and then removing the conductive material from between the patches. In the manufacturing process, the planar array of conductive patches can be deposited either, directly onto the dielectric separator, or onto a support made up of one or more layers of dielectric material.

[0021] For some of the reflector antenna applications, in which they should be attached to existing surfaces, in the manufacturing process of the multilayer reflector, the use of flexible materials allows the reflector to be shaped, in order

to fit pre-existing curved surfaces.

[0022] Another characteristic of the multilayer reflectarray compared with those of a single layer is that it allows the working frequency band to be increased. The frequency band of conventional reflectarrays is very narrow, avoiding their use in a large number of commercial applications. A factor that produces the band limitation is the difference in propagating distance for the rays that propagates from the feed (110) to the wave front (150), as shown in figure 9. In the reflectarray, the difference in propagating distances is compensated at the central frequency by means of a phase shift in each element. However, for other frequencies slightly separated from the central frequency, the phase compensation should be slightly different, since the wavelength changes, and the error will be bigger for larger difference of distances to be compensated. This error can diminish, and therefore to improve the bandwidth, with an appropriate choice of both the position of the feed and the direction of radiation. Figure 9 shows the lateral view of a configuration, in which the surface of the planar reflector (100) has been chosen as the aperture plane of an equivalent parabolic reflector (140) and the feed (110) has been located at the focus of the paraboloid. Therefore the propagating distances (160) and (170) are equal, i.e. the distances are the same in the whole contour of the reflectarray, minimising the phase to be compensated in the planar reflector and consequently a larger bandwidth is achieved. The other significant limitation in the band for reflectarrays based on patches of variable sizes is imposed by the strong dependence of the phase *versus* patch-size curves with frequency variations. The use of several array layers allows phase curves as a function of the size to be less sensitive to frequency variations, which produces an increase in bandwidth. Additionally, an adjustment in the dimensions of each element of the reflectarray can be carried out to improve the behaviour in the whole working band.

[0023] Because of the larger bandwidth of the multilayer configuration, and taking advantage of the low level of cross polarisation of the reflectarrays, another object of this invention consists of its application as dual polarisation reflectarrays as an alternative to grid reflectors. The phase correction in the reflectarray is carried out independently for each polarisation, allowing the use of two separate feeds (110) and (111) of linear polarisation, as shown in figure 10. If two feeds are used, one for each polarisation, located at different focal points, the dimensions of the conductive patches in each element are adjusted to compensate the position of each feed. The dimensions can also be adjusted in order to generate two collimated beams in different directions, one for each polarisation.

[0024] Another object of the invention consists of the use of the planar reflector as an antenna with multiple beams. To do that, the dimensions are adjusted in each element in order to obtain a phase distribution of the reflected field that provides several collimated beams in different directions, as shown in figure 11.

[0025] Another object of this invention is its application in the construction of folding reflectors. In some terrestrial or satellite communications applications, large reflectors that should be folded for transportation are required. Also folding reflecors are used in mobile terminal equipment. The multilayer planar reflector can be built in four or more pieces that can be stacked for transportation for later assembly. The assembly is not critical, since there is no electric contact between the metalisations of the reflectarray. The folding reflectors also have an important application field in onboard satellite reflectors, so that the reflector is folded during the launch and deployed in space.

[0026] A second main object of the invention is the procedure for designing a multilayer reflectarray in a given frequency band. This procedure provides the dimensions of all the metalisations and therefore the photo-etching masks, and it consists of the following steps:

1) Definition of the phase shift in each element. Once the working frequency, the position of the feed (110), or feeds (110) and (111), and the direction of radiation shown by arrows (130a) and (130b) are determined, the phase shift that should introduce each reflectarray element to achieve a reflected wave with a progressive phase distribution is computed. This phase distribution is defined for any polarisation, or for two orthogonal polarisations of the incident field. If the two polarisations come from a feed located at a focal point, the phase distribution is the same for the two polarisations, but if they come from two feeds located at different focal points, a phase distribution is defined for each polarisation. A phase distribution that produces a collimated reflected beam with a different polarisation to that of the incident field coming from the feed can also be defined. For example, a linear polarised feed can be considered and the phase distribution that produces a circular polarised collimated beam is defined, or vice versa. To do that, two different phase distributions must be defined, one for the linear polarisation with a field component in the direction of one side of the patches and the other with the incident field in the orthogonal direction, which differ by 90°. Other phase distributions can also be defined to produce two collimated beams in different directions, one for each polarisation, or several collimated beams in different directions, in the case of multiple beam antennas.

2) Adjusting the dimensions of each element at the central frequency. In this step the dimensions of the patches are determined to achieve the phase shift defined in the previous step for each radiating element at the given frequency. First, the curves of phase versus size are analysed at several frequencies for a periodic array of two or more layers on a metallic plane. In this step, square patches are considered in the two layers, as shown in figure

5, with those of the external layer being slightly smaller. Some geometry parameters are also determined at this step, as the thickness of the dielectric separators (420) and (430) placed between the array layers, the period ***a*** and the relative size of the patches in each layer in order to achieve a behaviour of the phase versus size which is smooth and less sensitive to frequency variations, as shown in figure 7. Next, the dimensions of each patch are determined using an iterative routine for zero finding. This routine calls the analysis program and adjusts the dimensions of each element until the phase defined in the step 1) is achieved. The procedure is repeated for each polarisation.

3) Performing fine adjustment to meet specifications in the working frequency band. Starting from the dimensions obtained in the previous step, a new adjustment of the conductive patch dimensions is carried out by using an optimisation routine. In this step, all the dimensions of the patches are adjusted simultaneously in order to meet the phase specifications defined in stage 1), for one or two polarisations, at one or several frequencies within the working band of the reflectarray.

[0027] Another object of this invention is the use of the multilayer planar reflector as a polariser, since it allows the phase in each element of the planar reflector to be adjusted in order to generate a collimated beam with a different polarisation than the incident field coming from the feed. An interesting application consists of generating a circular polarised beam from a linear polarisation feed, which is easier to build, or to receive a circular polarised beam concentrating it at the feed with linear polarisation.

[0028] Another object of the invention is its use as a conformal beam reflector. A conformal beam reflector such as those used in satellites for direct broadcast TV, consists of a reflector with deformities on its surface, so that the radiation diagram illuminates a certain geographical area. The design and construction of conformal beam reflectors should be carried out specifically for each application. For the construction of the conformal beam reflectors, moulds, which are very expensive to manufacture, are required and they cannot be reused for other antennas. The multilayer reflectarray and its design procedure can be used to adjust the phase in each element so that a conformal beam is achieved, with the same characteristics as that of a shaped reflector. The design procedure is the one described previously, but in the first step the phase shift at each element is defined to get a conformal beam, instead of a progressive phase. The construction of the conformal beam planar reflector is carried out by means of simple photo-etching techniques, which produce a significant reduction in the production costs by eliminating the expensive conformal moulds.

[0029] The planar reflector for collimated or conformal beam can be built for space applications, using the technology developed for the dichroic subreflectors. This technology uses materials qualified for space that basically consist of arrays of copper or aluminium metalisations (400 and 410) on very thin (between 25 and 160 microns) Kapton or Kevlar sheets (450 and 460) as shown in figure 8. As a dielectric separator (420 and 430) between different array layers, a kevlar core with a honeycomb structure can be used, which exhibits a very low dielectric constant (of approximately 1.05) and very low losses (loss tangent in the order of 10^{-3}). These materials are flexible and they allow a multilayer structure with metalisations that fit a curved surface to be built. Later on they are subjected to a curing process in which they acquire enough rigidity for their use in space applications.

[0030] In order to obtain a further bandwidth improvement in the conformal beam reflectors based on multilayer reflectarrays, they can be built in the shape of a parabolic reflector, and the phase is adjusted by varying the metalisation size only for the small phase differences that produce the conformal beam. Although the planar characteristic of the reflector is lost in this configuration, and consequently the manufacturing process is more complicated, conformal beam reflectors can be built with parabolic moulds, which are reusable for several applications and don't require such a rigorous technology as those with a conformal surface. Additionally, two independent feeds can be used, one for each linear polarisation, which are located in the vicinities of the paraboloid focus, and the dimensions of the conductive patches are adjusted in each element to compensate each feed position and to conform the beam in the two polarisations.

Explanation of the drawings

[0031] **Fig. 1**. Lateral view of a planar reflector (100) illuminated by a feed (110). In each element (120) of the reflector, an adjustment is introduced in the phase of the reflected field so that the divergent field coming from the feed (110) is reflected as a collimated beam in the direction of the arrows (130a) and (130b).

[0032] **Fig. 2**. Perspective of a planar array of conductive patches (200) deposited onto a sheet (210) of thickness **h**, made of dielectric material, also known as substrate, which is covered on the lower side by a conductor (230). The period is **a**.

[0033] **Fig. 3**. Perspective of a planar array of conductive patches (200) on a dielectric sheet and conductive plane, where the size of the patches (200) is different to get an adjustment in the phase of the reflected field. The period is **a**.

[0034] **Fig. 4**. Lateral view of a multilayer planar reflector illuminated by a feed (110) to produce a collimated beam

in the direction of the arrows (130a) and (130b) defined by the angles θ_0, ϕ_0 used in spherical co-ordinates. The planar reflector is made up of two layers of conductive patches (400) and (410) on dielectric material sheets, or substrate, (420) and (430), on a conductive plane (440). The two-layer element (300) represents a generic element ***l***.

[0035] **Fig. 5.** Lateral and frontal views of a square periodic cell of side **a**, used as element in the multilayer planar reflectors for the phase adjustment. The structure of the multilayer periodic element consists of a first rectangular conductive patch (400) of dimensions $\mathbf{a_1 x b_1}$, a dielectric separator (420) of thickness $\mathbf{h_1}$, a second rectangular conductive patch (410) of dimensions $\mathbf{a_2 x b_2}$, a second separator (430) of thickness $\mathbf{h_2}$, and a conductor plane (440).

[0036] **Fig. 6.** Phase of the reflection coefficient at normal incidence for a periodic array of square conductive patches on a ground plane, as shown in figures 2, as a function of the patch side, at three different frequencies, 11.5 (- - -), 12 (—) and 12.5 (-·-·-) GHz. The following data are assumed: periodic cell side **a**=14mm. and separator of relative dielectric constant 1.05 and thickness **h**=1mm.

[0037] **Fig. 7.** Phase of the reflection coefficient at normal incidence for a multilayer periodic array with periodic elements as shown in figure 5 as a function of the patch size at three different frequencies, 11.5 (- - -), 12 (—) and 12.5 (-·-·-) GHz. The following data are assumed: Square patches on the external layer 0.7 times the size of those on the intermediate layer ($\mathbf{a_1}$=$\mathbf{b_1}$, $\mathbf{a_2}$=$\mathbf{b_2}$, $\mathbf{a_1}$=0.7$\mathbf{a_2}$), separators of dielectric constant 1.05 and thickness $\mathbf{h_1}$ = $\mathbf{h_2}$=3mm and side of periodic cell, **a**=14mm.

[0038] **Fig. 8.** Perspective of the different layers that make up a multilayer planar reflector. From the upper layer to the lower one, first array of rectangular conductive patches (400) of different sizes, first dielectric substrate layer (450) onto which the patches are deposited, first dielectric separator (420), second array of patches (410), second substrate (460), second separator (430) and metallic plane (440).

[0039] **Fig. 9.** Lateral view of a configuration of planar reflector in which the propagation distances for a wave propagating from the feed (110) to the wave front (150) are same in the contour of the planar reflector. These distances are same for all the points of a parabolic reflector (140) with the feed (110) located at the focus.

[0040] **Fig. 10.** Lateral view of a multilayer planar reflector illuminated by two feeds (110) and (111) of different polarisation in which the adjustment of the dimensions of the conductive patches is carried out to generate a collimated beam in the direction of the arrows (130a) and (130b) for the two polarisations.

[0041] **Fig. 11.** Lateral view of a multilayer planar reflector illuminated by a feed (110) in which the adjustment of the dimensions of the conductive patches is carried out to produce two collimated beams in the directions shown by the arrows (130a-b) and (131a-b), respectively.

[0042] **Fig. 12.** Mask obtained by AUTOCAD to scale with the contour of the patches (400) of variable sizes for the first layer of a planar reflector designed to produce a collimated beam in the direction address θ_0=19°, ϕ_0=0° at 11.95 GHz.

[0043] **Fig. 13.** Mask obtained by AUTOCAD to scale with the contour of the patches (410) of variable sizes for the second layer of a planar reflector designed to produce a collimated beam in the direction address θ_0=19°, ϕ_0=0° at 11.95 GHz.

Details of the preferred embodiment:

[0044] In this section the steps for carrying out the design and construction of a planar reflector based on multilayer printed technology for dual polarisation are described.

[0045] First, the technology and the materials to be used in the realisation of the reflector are chosen. In the example that is described, a commercial foam, known as ROHACELL 51, has been chosen as the material for the separators between the layers with metalisations which has a relative dielectric constant of 1.05 and a loss tangent of 10^{-3}. The arrays of rectangular metallic patches are built starting from a metallised dielectric support of small thickness, such as for example, a 25 micron Kapton film with an 18 micron copper cladding. The Kapton has a relative dielectric constant of 3.5 and a loss tangent of $3x10^{-3}$, although owing to its small thickness its effect is negligible.

[0046] Once the materials have been chosen, a multilayer periodic structure is analysed, which is made up of two or more stacked layers of metallic patches on a metallic plane, separated by dielectric separators. A periodic cell is shown in figure 5 for the case of two layers. For the analysis of the multilayer periodic structure, a full wave method is used such as the well-known Moments Method in spectral domain, and the phase of the reflection coefficient is computed for the two possible polarisations of the incident field as a function of the different geometric parameters and excitation. Arrays of square resonant patches with the side of approximately half a wavelength are considered as starting point and the size is modified continuously to study the behaviour of the phase versus the resonant length. The size of the patches is varied simultaneously in all the layers maintaining a fixed ratio between the sizes in each layer and a fixed period in all the layers. It has been proven that the array closer to the ground plane should be made up of slightly larger patches. The variation in the reflection coefficient phase is analysed for each one of the two orthogonal polarizations, i.e. for an incident electric field with *x* component ($\mathbf{E_x}$), and for an electric field with *y* component ($\mathbf{E_y}$), for different angles of incidence and for several frequencies within the working band.

[0047] At this stage some geometric parameters, such as the patch repetition period **a**, the thickness of separators $\mathbf{h_1}$ and $\mathbf{h_2}$, and the relative size of the patches are adjusted in each layer in order to achieve a sufficiently linear phase variation as a function of the patch dimensions for different angles of incidence, for different frequencies and which cover at least a 360° phase range. For the implementation that is described, a design frequency f=11.95 GHz has been chosen, a structure of 2 layers of conductive patches has been considered and the following geometric values have been chosen:

- Thickness of ROHACELL: 3 mm.
- Repetition period: 14 mm.
- Relative size of patches top/bottom: 0.7

[0048] For these values, the curves of the reflection coefficient phase for the two polarisations, at normal incidence, are shown in figure 7, at frequencies 11.5, 12 and 12.5 GHz.

[0049] Next, the position of the feed with respect to the reflector, the size of the reflector and the direction of radiation are fixed. For this implementation, a circular reflector of 40cm in diameter has been considered, and a commercial feed used in satellite television receivers from the company SATELITE ROVER, with reference FOLWR75, has been used. The reflector is located on the **XY** plane with its centre in the origin of the co-ordinates, the centre of the feed aperture is placed at co-ordinates, $\mathbf{x_f}$ = -116, $\mathbf{y_f}$ = 0, $\mathbf{z_f}$ = 340mm., and the angle of radiation is fixed to θ_0=19°, ϕ_0=0°, in spherical co-ordinates.

[0050] With these data the design of the reflector in printed technology is carried out to determine the photo-etching mask for the patches in each layer. The process consists of three steps:

1) Defining the phase shift in each element. Once the position of the feed (110) and the direction of radiation, defined by the angles θ_0, ϕ_0 in spherical co-ordinates are determined, the phase shift that should be introduced at each element (300) of the reflectarray is computed to get a progressive phase distribution of the reflected wave. Since the reflector is in the far field zone of the feed, the phase of the incident field on each element ***l*** (300) of the reflectarray is the product of the wave number K_0 by the distance from the feed to the element ***l***, known as $\boldsymbol{d_l}$, To obtain a field reflected in the direction (θ_0, ϕ_0) its phase on the surface of the reflector should be,

$$Phase(x,y)=-K_0 \sin\theta_0\,(x\cos\phi_0 + y\sin\phi_0),$$

(x,y) being the co-ordinates of each point on the surface of the reflector. To get this phase distribution, each element ***l*** of the reflector should introduce a phase shift in the reflection coefficient,

$$Refl.\ Coeff.\ Phase\ (x_l,y_l)= K_0\,[d_l - \sin\theta_0\,(x_l\cos\phi_0 + y_l\sin\phi_0)],$$

where (x_l,y_l) are the co-ordinates of the centre of element ***l***. This is the objective phase of the reflection coefficient that should be obtained for the two orthogonal polarisations if only one feed is used.

2) Adjusting the dimensions of each element at the central frequency. In this stage the dimensions of the patches are determined in order to achieve the phase shift defined in the previous step in each radiating element at the central frequency.

If the direction of the incident field in the reflector were perpendicular to this, the phase of the reflection coefficient would be the same for the two polarisations. However, in the reflectarray the incidence is oblique in each element and the phases for each polarisation will be different. Therefore, to obtain a progressive phase in the reflected field for the two orthogonal polarisations, $\mathbf{E_x}$ and $\mathbf{E_y}$, the two dimensions of each patch should be adjusted. Since the phase for each polarisation practically depends on the resonant dimensions only, first square patches are assumed and the dimensions $\mathbf{a_1}$ and $\mathbf{a_2}$ are adjusted, see figure 5, to obtain the required phase for the $\mathbf{E_x}$ polarisation. Later, $\mathbf{b_1}$ and $\mathbf{b_2}$ are adjusted, also assuming square patches, for the phase of $\mathbf{E_y}$.

For the analysis of the reflectarray, the phase of the reflection coefficient is computed for each polarisation in every period assuming local periodicity, i.e. analysing each element with its dimensions in a periodic environment.

To determine the dimensions of each patch, an iterative routine based on the 'false position' method is used. The routine calls the analysis program and adjusts the dimensions of each element until the required phase is obtained. The iterative procedure is applied for square patches to get the phase distribution defined in the previous

step for E_x field polarisation and the dimensions a_1 a_2 are obtained. Next, the procedure is applied for E_y field polarisation and the dimensions b_1 b_2 are obtained. The patch dimensions a_1, b_1, a_2 and b_2 in each element of the reflector provide, within a very good approximation, the phase distributions defined in stage 1) for the two polarisations.

3) Performing fine adjustment to meet the specifications in the working frequency band. Starting from the dimensions obtained in the previous stage, a new adjustment of the dimensions is carried by using an optimisation routine in order to meet the phase specifications in each element for the two orthogonal polarisations at several frequencies within the reflectarray working band. To do this, an objective phase for the reflection coefficient is determined at each frequency, for each element of the reflector, and a phase error is defined for each polarisation as the difference between this objective phase and the phase computed by the Moments Method. An error function is defined as the sum of the square of the phase errors for each polarisation at every frequency. The optimisation routine adjusts all the dimensions of the patches (**a1**, **a2**, **b1** and **b2**) in each element to minimise the error function. This process provides all the dimensions of the metallic patches in the two layers which allow the photo-etching mask to be generated.

[0051] For the technological implementation of the reflectarray, the traditional photo-etching techniques used in the production of printed circuits can be used. In the implementation here described, the photo-etching masks for each reflectarray layer have been generated with AUTOCAD from the file with the dimensions of the patches obtained in the design stage. Figures 12 and 13 show the masks to scale with the contours of the rectangular patches for the first and second array layers, respectively. The rectangular patches have been cut from a copper-clad Kapton sheet by a cutting plotter using the AUTOCAD files. Afterwards, the patches are transferred to a 100 micron adhesive film, and this sheet is then adhered to the ROHACELL which acts as separator. A copper-clad Kapton sheet has been used as the metallic plane.

[0052] This prototype has been built and measured in an anechoic chamber. The measured characteristics of the reflector meet the specifications considered in the design. The radiation patterns are practically the same for the two linear polarisations and they coincide with those obtained by the analysis method. The gain is 31 dB, with ±0.15dB gain variations in the 11.5 to 12.4 GHz band. The cross polarisation is below -33dB.

Industrial application

[0053] As already mentioned in previous sections, this invention can be applied to reflector antennas in radar and both terrestrial and satellite communications, with significant advantages compared to conventional parabolic reflectors. Because of the planar characteristic, it can be built in several pieces to be folded and later deployed, being of great use in applications in which large reflectors that need transporting are required. Owing to the fact that is a planar reflector with the possibility of redirecting the beam, it can be fitted to existing structures, such as building walls, structural planes in communication satellites, etc. It can be used as a dual polarisation reflector with an isolation level between polarisations better than those obtained with conventional reflectors.

[0054] The present invention can be built using space qualified materials and a technology already developed in space applications for the manufacture of dichroic subreflectors. Therefore, this type of multilayer planar reflectors is very suitable for a significant range of applications in the space industry as an alternative to the different types of onboard reflectors in satellites, such as parabolic, grid or shaped reflectors.

Claims

1. A planar reflector in printed circuit technology characterized by reflecting the electromagnetic energy coming from a feed located at a focal point forming a collimated beam in a given direction at a given frequency, or reflecting a collimated beam coming from a given direction at a given frequency by concentrating it at the focal point where the feed is located, and characterised by having at least two layers of conductive patch arrays, that consists of: a conductive plane, a sheet of dielectric material called separator, a thin film of dielectric material that supports a planar array of rectangular conductive patches, a new separator layer and a new layer of conductive patches on a dielectric support; in which the dimensions of the conductive patches in each layer are adjusted individually to achieve a phase shift in the reflected field to collimate the electromagnetic field coming from the feed or to concentrate the collimated beam incident onto the reflector at the feed.

2. Planar reflector according to claim 1, wherein the conductive patches are deposited directly onto the dielectric separator.

3. Planar reflector according to claim 1, characterised by having more than two layers of dielectric material between the conductor plane and the conductive patches, or between the planar arrays of patches.

4. Planar reflector according to claim 1 and claims 2 to 3 or anyone of them, built in materials qualified for space applications.

5. Planar reflector according to claim 1 and claims 2 to 4 or anyone of them, characterised by having more than two layers of conductive patch arrays and stacked dielectric sheets.

6. Planar reflector as in claims 1 and claims 2 to 5 or anyone of them, wherein the conductive patches in any layer are square or in the shape of a cross, instead of rectangular.

7. Planar reflector according to claim 1 and claims 2 to 6 or anyone of them, wherein the patch array in each layer is manufactured by means of selective elimination of conductive material from a dielectric sheet covered by a conductive film, by means of photo-etching and chemical etching techniques, or by selective elimination of the conductive material by laser, or cutting the conductive patches by using a cutting plotter and removing the conductive material between the patches.

8. Planar reflector according to claim 1 and claims 2 to 7 or anyone of them, characterised by being built in several pieces to be folded and deployed.

9. Planar reflector according to claim 1 and claims 2 to 7 or anyone of them, characterised by being built in flexible materials to be fitted to curved surfaces.

10. Method for design characterized by obtaining the photo-etching masks for the construction of a planar reflector made up of several layers of planar arrays of conductive patches separated by dielectric sheets on a conductor plane, and that consists of the following steps: 1) defining the phase of the reflection coefficient for each element so that the electromagnetic energy of a certain frequency coming from a feed located at a focal point is reflected forming a collimated beam in a certain direction, where each element is made up of two or more stacked conductive patches above a conductor plane separated from each other and from the conductor plane by dielectric sheets; 2) determination of the patch dimensions so that the phase of the reflection coefficient in each element defined in the previous stage is achieved, by using an iterative routine for zero searching that adjusts the patch dimensions and computes the reflection coefficient by an analysis method of multilayer periodic structures, based on the Moments Method, until required phase is achieved; 3) fine adjustment of the conductive patch dimensions in each element of the multilayer reflector, by means of an optimisation routine, to achieve the phase defined in stage 1) for an incident field with any polarisation type for one or several frequencies within the working band of the reflector.

11. Method for design according to claim 10, wherein the adjustment of the dimensions of the conductive patches in each element in stages 2) and 3) is carried out simultaneously for two independent orthogonal polarisations of the incident field.

12. Method for design according to claims 10 and 11, wherein the phase of the reflection coefficient is defined in stage 1) for two independent feeds, one for each of the two orthogonal polarisations, located at different focal points.

13. Method for design according to claim 10 and claims 11 to 12 or anyone of them, wherein the phase of the reflection coefficient is defined in stage 1) so that the field coming from the feed or feeds is reflected forming two collimated beams, one for each polarisation of the incident field, in different directions.

14. Method for design according to claim 10, wherein the phase of the reflection coefficient is defined in stage 1) so that the field coming from the feed is reflected forming a collimated beam with a different polarisation than that of the incident field.

15. Method for design according to claim 10 and claims 11, 12 and 14 or anyone of them, wherein the phase of the reflection coefficient is defined in stage 1) so that the field coming from the feed or feeds is reflected forming a conformal beam, instead of a collimated beam.

16. Method for design according to claim 10 or claims 10 and 11, wherein the phase of the reflection coefficient is defined in stage 1) so that the field coming from the feed is reflected forming several collimated beams in different

directions.

17. Planar reflector according to claims 1 to 6 and 10 to 11 or anyone of them, wherein the phase of the reflection coefficient is defined, and the dimensions of the patches are adjusted in each element to collimate the beam coming from the feed, or to concentrate the collimated beam incident on the reflector at the focal point where the feed is located, with the same characteristics as those of a parabolic reflector.

18. Planar reflector according to claims 1 to 6 and 10 to 11 or anyone of them, wherein the dimensions of the conductive patches in each layer are adjusted to collimate the beam coming from the feed, or to concentrate the collimated beam incident on the reflector at the focal point where the feed is located, for two polarisations of the electromagnetic field simultaneously.

19. Planar reflector according to claims 1 to 6 or anyone of them, characterised as having two feeds located at two different focal points that works in orthogonal polarisations, which is designed according to claims 10 to 12 so that, the beams coming from the two feeds are reflected forming collimated beams in the same predetermined direction.

20. Planar reflector according to claims 1 to 6 and 10 to 13 or anyone of them with one or two feeds working in two orthogonal polarisations, characterised by generating or receiving two collimated beams, one for each polarisation of the incident field, in different directions.

21. Planar reflector according to claims 1 to 6 or anyone of them, and claims 10 and 14, wherein the dimensions of the conductive patches are adjusted in each layer to get a collimated reflected beam with circular polarisation when a linear polarised field coming from the feed is incident, or to concentrate at the focal point of the feed a linear polarised field when a collimated field with circular polarisation impinges on the reflector.

22. Planar reflector according to claims 1 to 6, 18, 19 and 21 or anyone of them, wherein the dimensions of the conductive patches in each element are adjusted to achieve the electric characteristics of a conformal beam reflector.

23. Multilayer Reflector according to claims 1 to 6, 18, 19, 21 and 22 or anyone of them, characterised by being parabolic in shape, instead of planar, with the feed or feeds near the focus of the paraboloid, wherein the dimensions of the conductive patches in each element are adjusted to achieve the electric characteristics of a conformal beam reflector, for single or dual polarisation.

24. Planar reflector according to claims 1 to 6 or anyone of them and claims 10 and 16, with a feed working in simple or dual polarisation, characterised by generating several collimated beams in different directions, or receiving electromagnetic signals from different directions and concentrating them at the focal point where the feed is located.

25. Planar reflector according to claims 1 to 23 or anyone of them wherein the dimensions of the patches are adjusted in each element to achieve a collimation, redirection, shaped or change of polarisation of the beam at several frequencies within the working band of the reflector.

Amended claims under Art. 19.1 PCT

1. A planar reflector in printed circuit technology that reflects the electromagnetic energy coming from a feed (110) located at a focal point, forming a collimated beam in a given direction at a given frequency, or that receives a collimated beam from a given direction at a given frequency and reflects it by concentrating it at the focal point where the feed is located, characterised by having at least two layers of conductive patch arrays with which a smaller sensibility to the manufacturing tolerances and a larger bandwidth are obtained, that consists of: a conductive plane (440), a sheet of dielectric material called a separator (430), a thin film of dielectric material (460) that supports a planar array of rectangular conductive patches (410), a new separator layer (420) and a new layer of conductive patches (400) on a dielectric support (450); in which the dimensions of the conductive patches in each layer are adjusted individually to achieve a phase shift in the reflected field to collimate the electromagnetic field coming from the feed or to concentrate the collimated beam incident onto the reflector at the feed.

2. Planar reflector according to claim 1, wherein the conductive patches are deposited directly onto the dielectric separator.

3. Planar reflector according to claim 1, characterised by having more than two layers of dielectric material between the conductor plane (440) and the conductive patches (410), or between the planar arrays of patches (400 and 410).

4. Planar reflector according to claims 1, 2 or 3, built in materials qualified for space applications.

5. Planar reflector according to claims 1, 2, 3 or 4, characterised by having more than two layers of conductive patch arrays and stacked dielectric sheets.

6. Planar reflector as in claims 1, 2, 3, 4 or 5, wherein the conductive patches in any layer are square, rectangular or in the shape of a cross.

7. Planar reflector according to claim 6, wherein the patch array in each layer is manufactured by means of selective elimination of conductive material from a dielectric sheet covered by a conductive film, by means of photo-etching and chemical etching techniques, or by selective elimination of the conductive material by laser, or cutting the conductive patches by using a cutting plotter and removing the conductive material between the patches.

8. Planar reflector according to claim 6 or 7, characterised by being built in several pieces to be folded and deployed.

9. Planar reflector according to claim 6 or 7, characterised by being built in flexible materials to be fitted to curved surfaces.

10. Method for design to obtain the photo-etching masks for the construction of a planar reflector made up of several layers of planar arrays of conductive patches separated by dielectric sheets above a

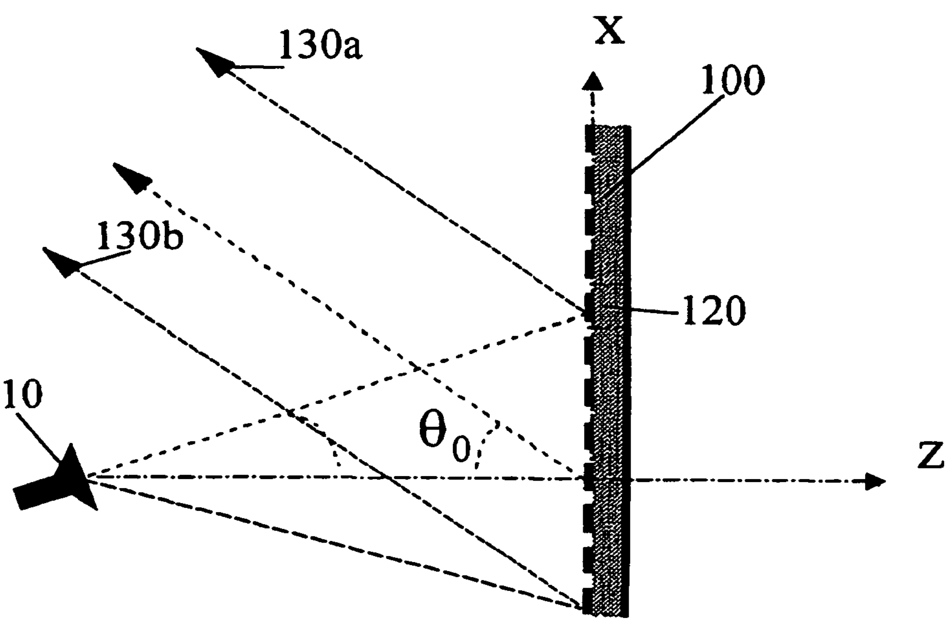

Fig. 1

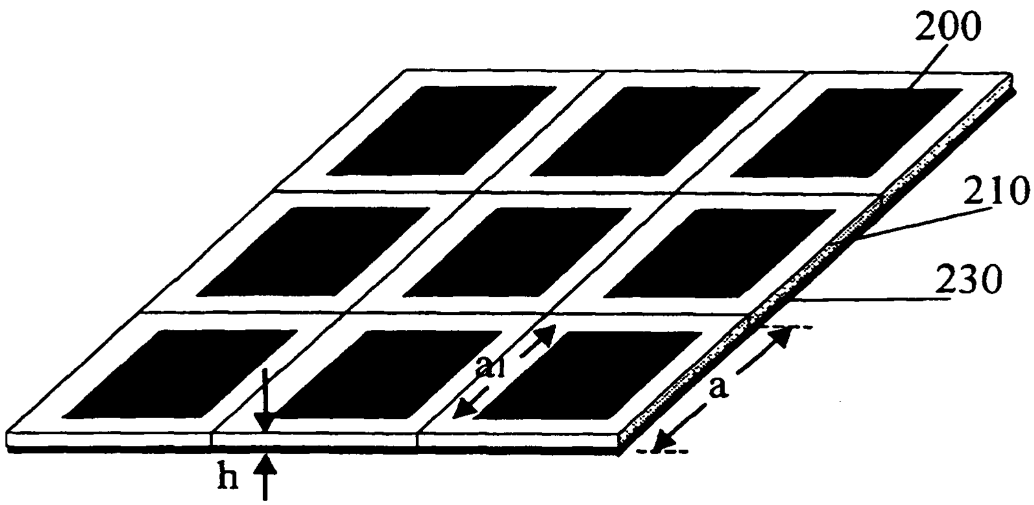

Fig. 2

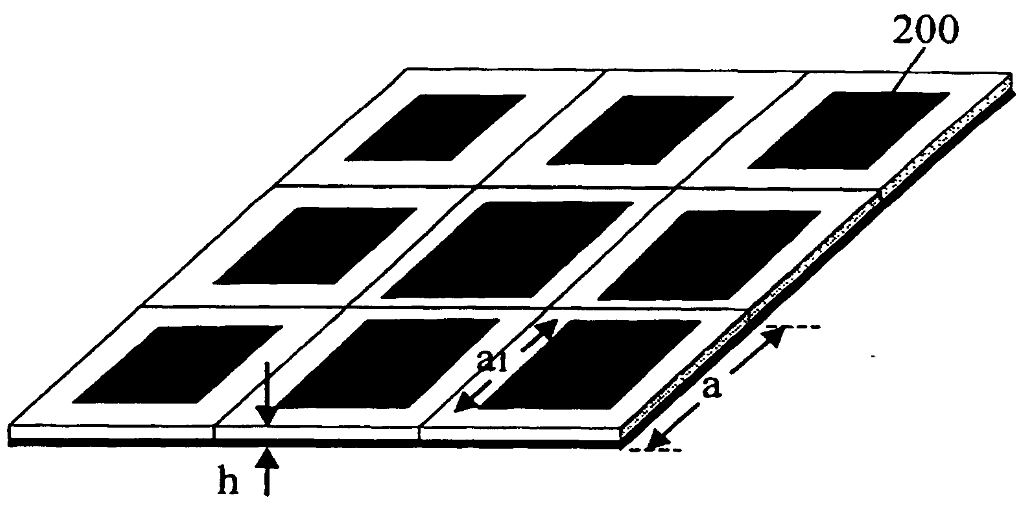

Fig. 3

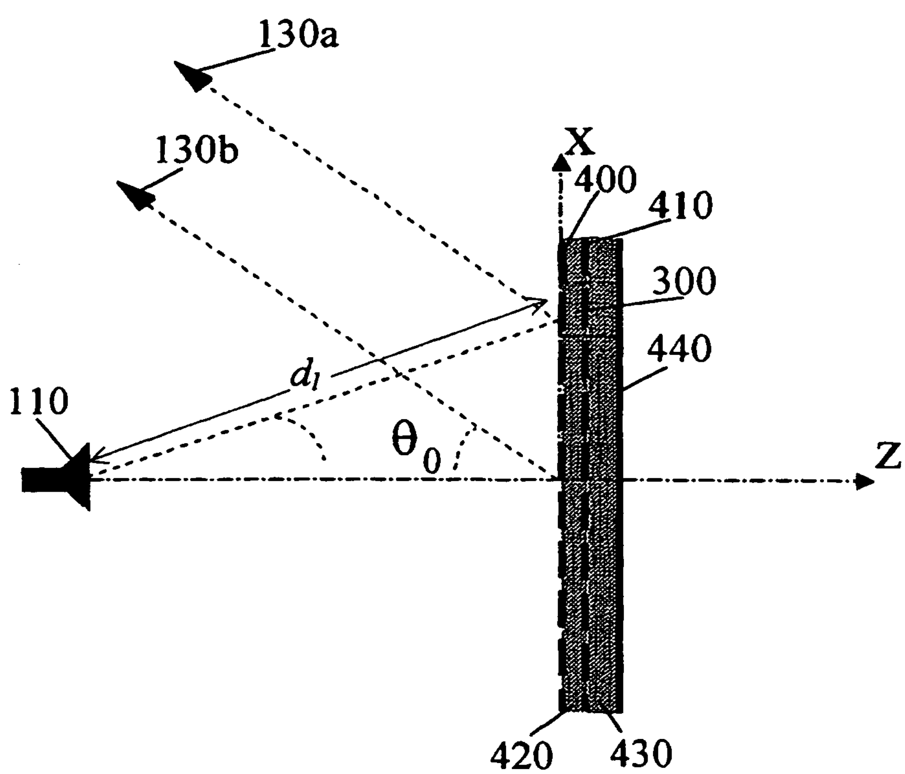
130a
130b
X
400
410
300
440
d_l
110
θ_0
Z
420
430

Fig. 4

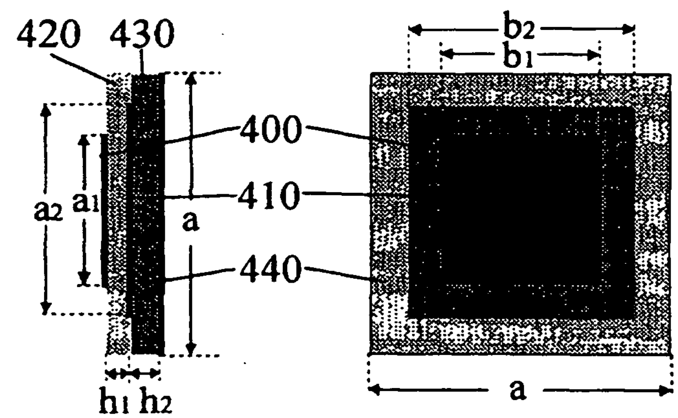
420
430
b_2
b_1
400
410
440
a_2
a_1
a
h_1
h_2
a

Fig. 5

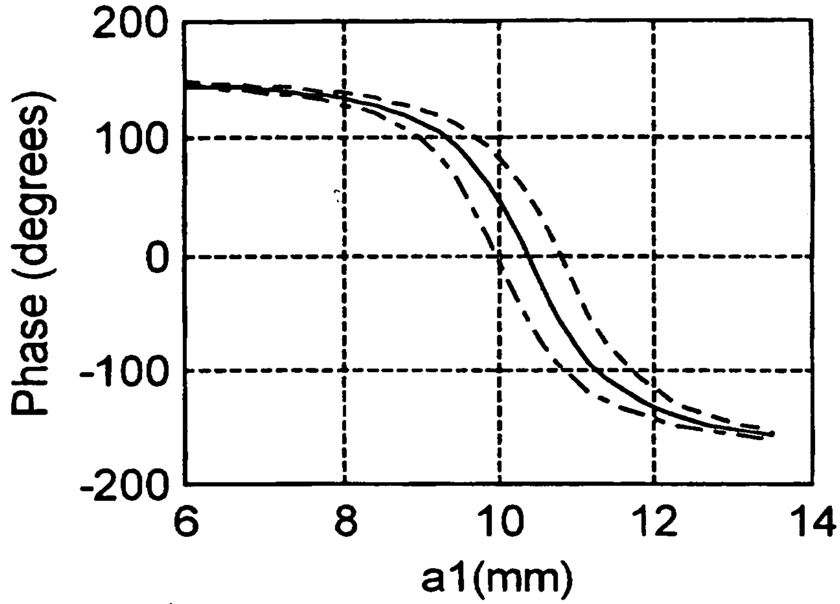
200
100
0
-100
-200
Phase (degrees)
6
8
10
12
14
a1(mm)

Fig. 6

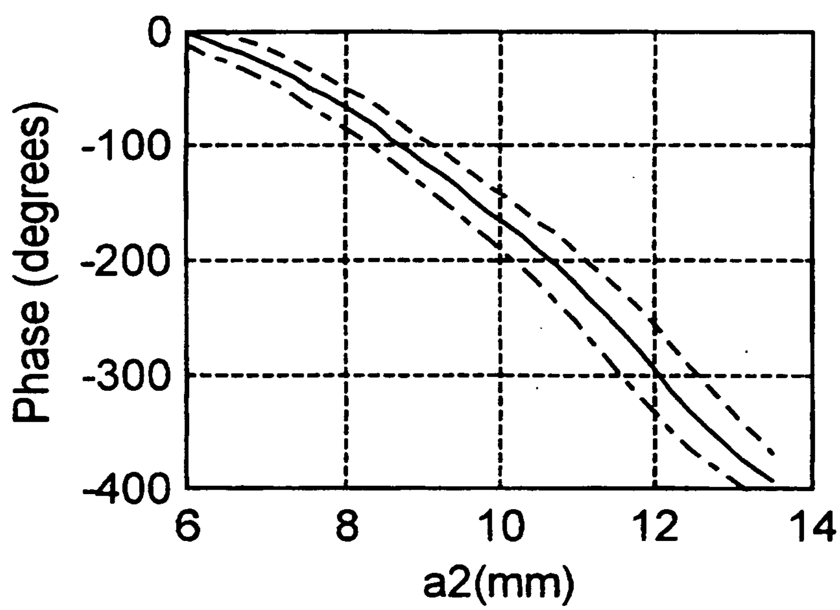
0
-100
-200
-300
-400
Phase (degrees)
6
8
10
12
14
a2(mm)

Fig. 7

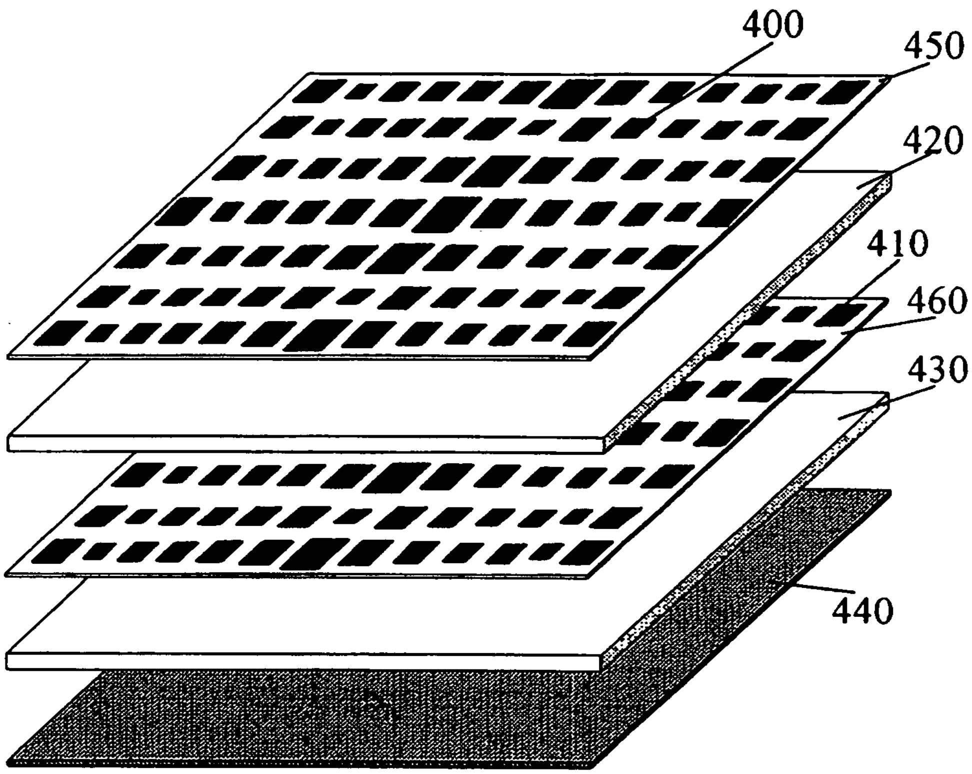

Fig. 8

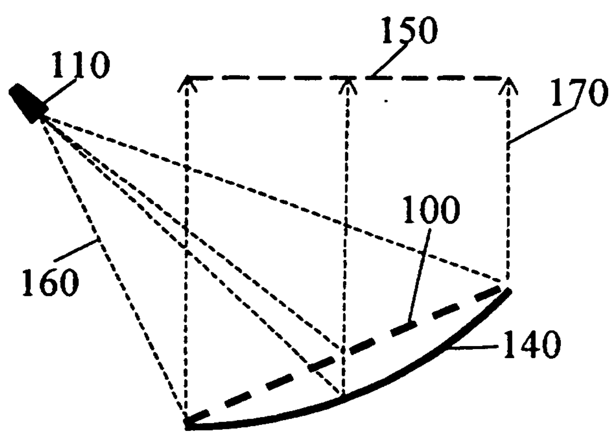

Fig. 9

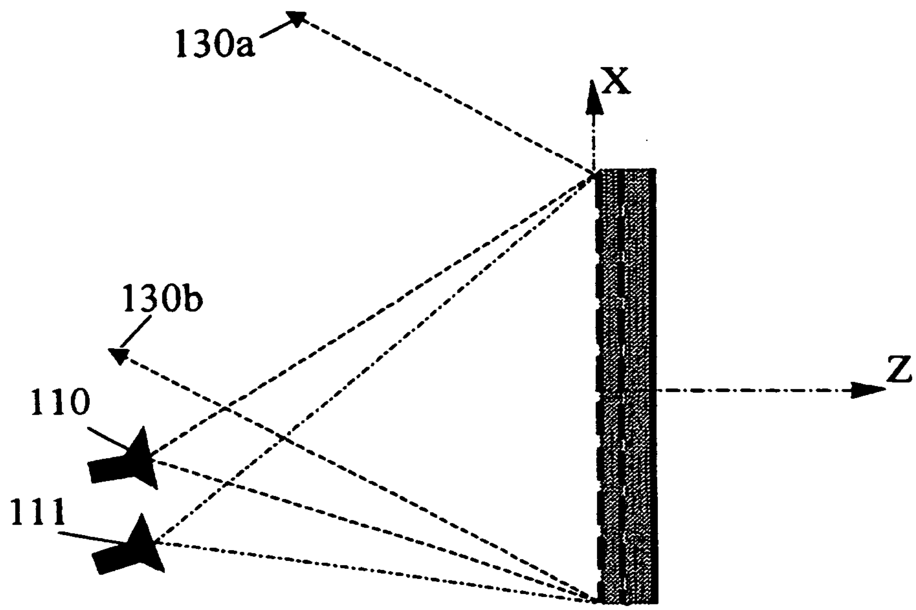

Fig. 10

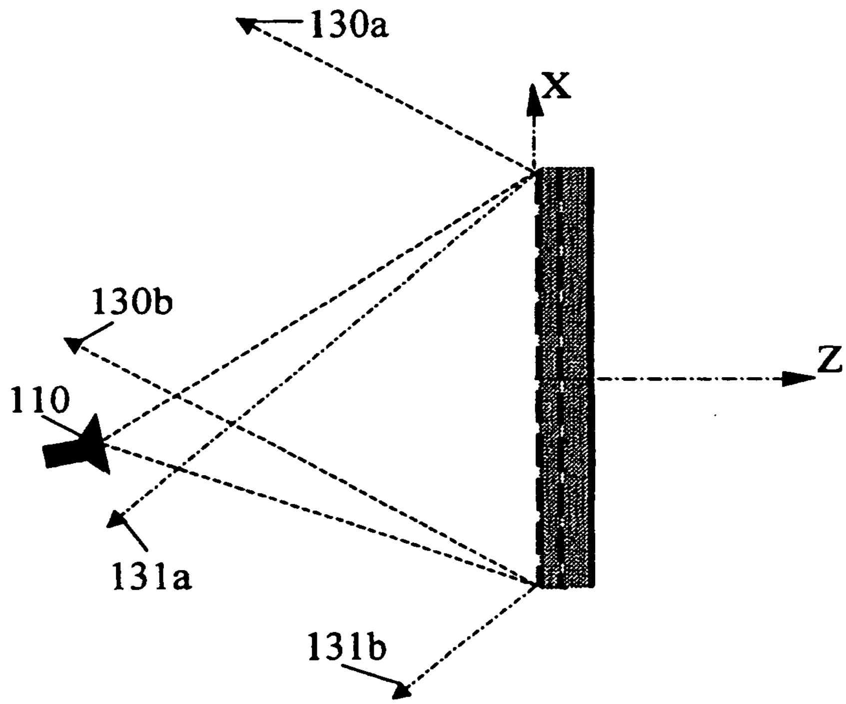

Fig. 11

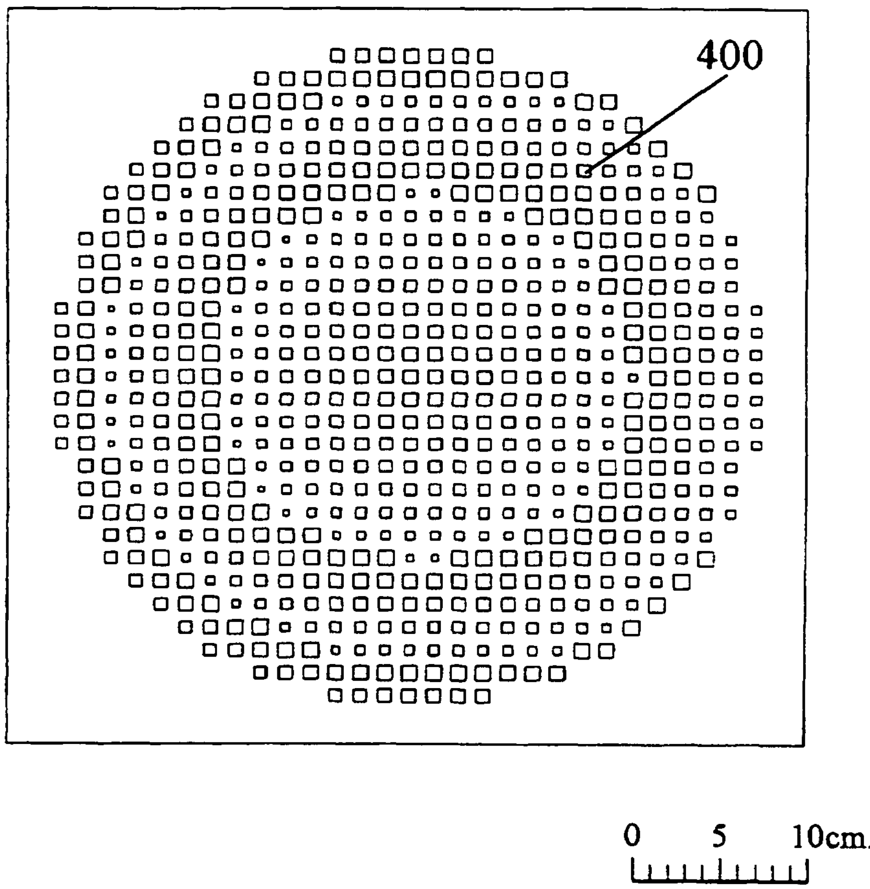

Fig. 12

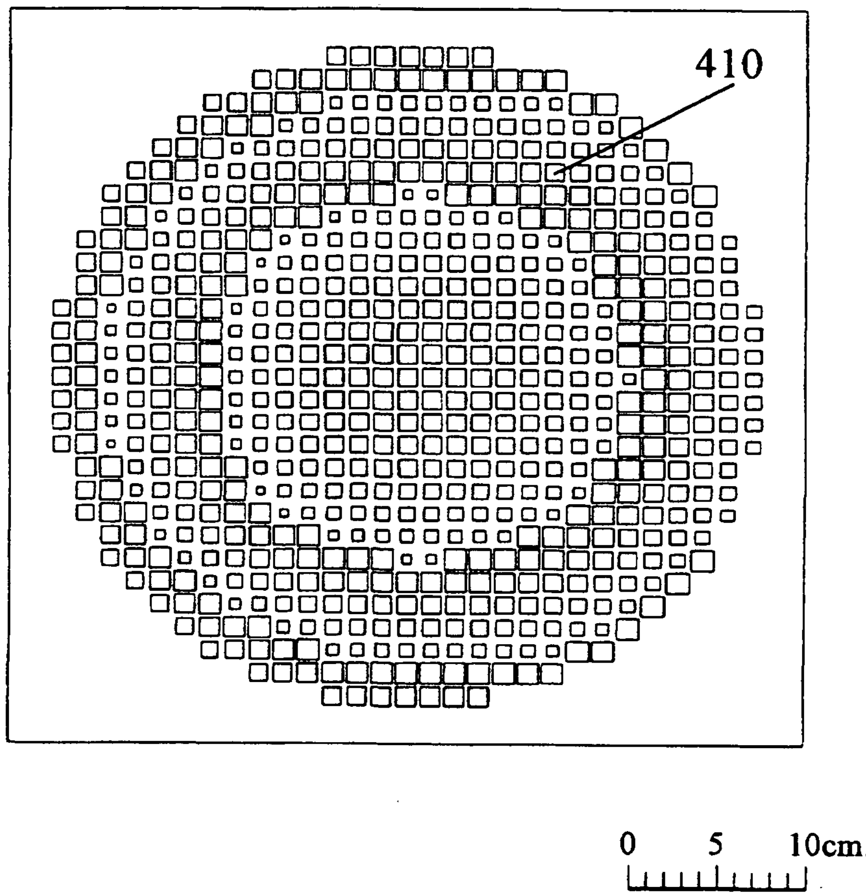

Fig. 13

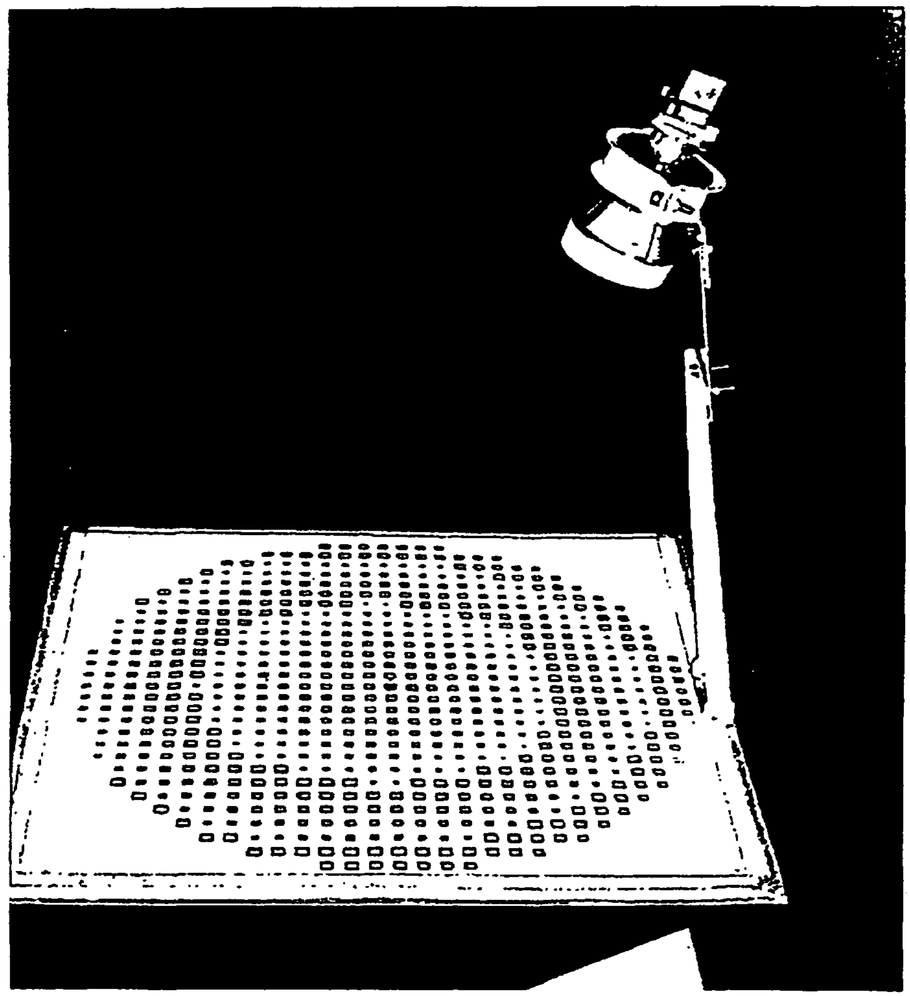

Fig. 14

INTERNATIONAL SEARCH REPORT

International application No.
PCT/ES 00/00203

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01Q 3/46, 21/00
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01Q 3/00, 5/00, 15/00, 21/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPODOC, WPI, PAJ, CIBEPAT, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	ENCINAR, J. A. « Design of two-layer printed reflectarraysfor bandwidth enhancement » IEEE Antennas and Propagation Society International symposium. 11-16 July 1999 (11-16.07.99) volume 2, pages 1164-7.	1,2,10
X Y	ENCINAR, J. A. « Design of a dual frequency reflectarry using microstrip stacked patches of variable size ». Electronic Letters. 6 June 1996 (06.06.96), Volume 32, no. 12, pages 1049-50.	1,2 4,6,7,9,19
Y A	US 5543809 A (PROFERA, Jr.) 6 August 1996 (06.08.96) The whole document.	4,9,19 1,11,12,23
Y A	US 4684952 A (MUNSON et al.) 4 August 1987 (04.08.97) The whole document.	6,7,9,19 1
A	WAN and ENCINAR, J. A. « Efficient Computation of Generalised Scattering Matrix for Analysing Multilayered Periodic Structures » IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION. November 1995 (11.2000) Volume 43, no. 11, pages 1233-42.	10

☒ Further documents are listed in the continuation of box C.   ☒ Patent family members are listed in annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
04 August 2000(04.08.00)	28 August 2000 (28.08.00)
Name and mailing address of the S.P.T.O	Authorised officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 1992)